

Non-Recycled Pulsars in Globular Clusters

Ryan S. Lynch^{*}, Jason R. Boyles[†], Duncan R. Lorimer[†], Robert Mnatsakanov^{**}, Philip J. Turk^{**} and Scott M. Ransom[‡]

^{*}*Department of Astronomy, University of Virginia, P.O. Box 400325, Charlottesville, VA 22904*

[†]*Department of Physics, West Virginia University, P.O. Box 6315, Morgantown, WV 26506*

^{**}*Department of Statistics, West Virginia University, P.O. Box 6330, Morgantown, WV 26506*

[‡]*National Radio Astronomy Observatory, 520 Edgemont Road, Charlottesville, VA 22903*

Abstract. We place limits on the population of non-recycled pulsars originating in globular clusters through Monte Carlo simulations and frequentist statistical techniques. We set upper limits on the birth rates of non-recycled cluster pulsars and predict how many may remain in the clusters, and how many may escape the cluster potentials and enter the field of the Galaxy.

Keywords: pulsars: general—globular clusters: general

PACS: 97.60.Gb, 98.20.G

INTRODUCTION

Lyne et al. [1] noted the presence of long-period, relatively high magnetic field pulsars in globular clusters (GCs) that seem more similar to the “normal”, non-recycled pulsars (NRPs) commonly found in the Galactic disk; four such pulsars are currently known [2, 3, 1, 4]. Their presence is an enigma, as NRPs are commonly assumed to form via core collapse of a massive star and to live as pulsars for ~ 10 – 100 Myr, but no massive stars have existed in GCs for ~ 10 Gyr. One popular explanation for the presence of NRPs in GCs is accretion induced collapse (AIC) of a massive white dwarf [5, and references therein], but AIC have not been directly observed and the properties of neutron stars formed through this channel are not well known.

We set out to use the sensitivity limits of dozens of GC pulsar searches to estimate upper limits on the birth rates of NRPs in clusters. We make no assumptions about the processes leading to their formation, so these results may be applied to a variety of channels. We then use the implied birth rates to model a population of NRPs that have escaped from clusters and entered the field of our Galaxy.

NRPs RETAINED IN CLUSTERS

Observing parameters from 54 GC searches were used to compute limiting flux densities, which were then converted to limiting luminosities (L_{\min}) using published GC distances. As the known NRPs in clusters appear similar to normal Galactic pulsars, we used the luminosity function given in Faucher-Giguère and Kaspi [6] and a typical lifetime of 40 Myr. Since GCs have relatively low escape velocities (~ 50 km s^{−1}), many NRPs will escape the clusters due to birth kicks. We simulated birth rates for three Maxwellian kick distributions with $\sigma = 10, 130$, and 265 km s^{−1}. Kick velocities were

chosen at random for each distribution and compared to published escape velocities for each cluster—if $v_{\text{psr}} < v_{\text{esc}}$, the pulsar was assumed to be retained by the cluster and assigned a luminosity, also chosen at random. The number of trials to obtain one observable pulsar was computed, which was taken to be an estimated upper limit for the number of NRPs in a particular cluster for the given velocity distribution, which was then divided by the assumed lifetime to arrive at a birth rate.

We also used an approach that assumes the number of observable pulsars is described by a binomial distribution. In clusters with no known NRPs, this reduces to $P(N, n = 0) = (1 - p)^N$, where N is the total number of NRPs, n is the number detected, and p is the probability that $L_{\text{psr}} > L_{\text{min}}$. The results for both approaches are similar and predict an upper limit of ~ 5000 NRPs across the clusters we have studied.

NRPs THAT ESCAPE FROM CLUSTERS

The birth rates calculated above for each velocity distribution were used to estimate the number of NRPs that will escape from their host clusters. The motion of pulsars with velocities sufficient to escape the cluster were integrated through the Galactic potential. Birth properties were assigned according to the distributions in Faucher-Giguère and Kaspi [6] and evolved accordingly. This population was then subjected to model pulsar searches using the PSRPOP¹ software suite. We used two approaches to simulate data for our models. The first used the exact birth rates described above, using the median value for clusters with unknown birth rates. However, this method does not provide very useful constraints (i.e., the upper limits are very large), so we also assigned each cluster a birth rate that was scaled by the V-Band luminosity of the cluster, with M22 (our most sensitively searched cluster) used as a reference. Our reasoning here is that the birth rates should scale with the number of stars in the cluster, roughly given by the luminosity. We are exploring other scalings as well.

We find that it may be possible for future pulsar surveys using Square Kilometer Array-like telescopes to detect a population of NRPs that originated in GCs, if the birth rates are sufficiently high. The pulsars could be separated from field pulsars by their differing kinematics. However, this depends on the assumed birth rates, which in turn depend on search sensitivities, so deeper searches are needed to draw firm conclusions.

ACKNOWLEDGMENTS

We gratefully acknowledge support from the National Science Foundation through grant AST-0907697.

REFERENCES

1. A. G. Lyne, R. N. Manchester, and N. D’Amico, *ApJ* **460**, L41+ (1996).

¹ <http://psrpop.sourceforge.net/>

2. A. G. Lyne, J. D. Biggs, P. A. Harrison, and M. Bailes, *Nature* **361**, 47–49 (1993).
3. J. D. Biggs, M. Bailes, A. G. Lyne, W. M. Goss, and A. S. Fruchter, *MNRAS* **267**, 125–+ (1994).
4. A. M. Chandler, *Pulsar searches: From radio to gamma-rays*, Ph.D. thesis, CALIFORNIA INSTITUTE OF TECHNOLOGY (2003).
5. N. Ivanova, C. O. Heinke, F. A. Rasio, K. Belczynski, and J. M. Fregeau, *MNRAS* **386**, 553–576 (2008), 0706.4096.
6. C. Faucher-Giguère, and V. M. Kaspi, *ApJ* **643**, 332–355 (2006), arXiv:astro-ph/0512585.